

DOCKET NO: 99RE166

UNITED STATES PATENT APPLICATION

OF

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FOR

ELECTRIC MOTOR STATOR ASSEMBLY  
HAVING NOVEL WINDING ARRANGEMENT  
AND METHOD OF MAKING SAME

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ELECTRIC MOTOR STATOR ASSEMBLY  
HAVING NOVEL WINDING ARRANGEMENT  
AND METHOD OF MAKING SAME

Background of the Invention

5           The present invention relates generally to the  
art of electric motors and other electromechanical  
machines. More particularly, the invention relates to  
an improved winding arrangement for the stator of an  
electromechanical machine.

10           Electric motors and other electromechanical  
machines are generally constructed having a  
cylindrical stator core. The inner circumference of  
the stator core defines a plurality of radial slots in  
which electrical windings are maintained. As is well  
15           known, current flow through the windings produces a  
rotating magnetic field which the rotor of the machine  
will tend to follow.

20           The stator windings of an AC induction motor are  
typically arranged into a plurality of coil groups,  
with each coil group providing a single pole of a  
single phase. Each side of an individual coil  
typically shares a particular winding slot with one  
side of another coil in a different coil group. Thus,  
a common three-phase, two-pole induction motor will  
25           have a total of six coil groups. Typically, each of  
the coil groups in such a motor will be configured  
having eight coils, yielding a total of forty-eight  
coils. These forty-eight coils have a total of

ninety-six coil sides, located in forty-eight winding slots.

The art has developed several winding patterns in which the coil groups can be arranged. For example, one arrangement that has seen widespread use in industry is the "lap winding." In this arrangement, one side of a coil will be in the "bottom" of a particular winding slot, while the other side of the same coil will be positioned in the "top" of another slot several slot positions away. Moreover, the respective sides of every coil will be separated by the same number of slot positions. Thus, the individual coils overlap each other around the inner circumference of the stator core.

Another common winding arrangement is referred to as a "concentric winding." In this type of arrangement, coils within a group are organized concentrically, such that sides of each coil will be separated by a different number of slot positions.

"Lap windings" and "concentric windings" each offer certain advantages not offered by the other. For example, lap windings typically exhibit outstanding operational characteristics. The lap winding process, however, has been extremely difficult to automate. Concentric windings, on the other hand, are amenable to automation. Thus, concentric windings are often preferred when motor cost is a significant factor.

While cost considerations tend to make the use of concentric windings desirable, it has not been possible to provide concentric windings in all motor sizes. For example, it has been found necessary to manually wind motors of 200 HP or larger with a lap winding pattern. This is due to the nature of a concentric winding pattern, in which the motor's lead wires must be attached to only one side of the stator core. With the large lead wires required at higher power levels, a standard frame size, such as a NEMA 440 frame, simply does not provide sufficient clearance to route the lead wires to the frame's conduit box opening. A lap winding pattern permits smaller lead wires to be connected at each end of the stator core, which are more easily routed to the conduit box opening in the frame.

#### Summary of the Invention

The present invention recognizes and addresses the foregoing disadvantages, and others, of prior art constructions and methods. Accordingly, it is an object of the present invention to provide a novel winding arrangement for the stator of an electromechanical machine.

It is a more particular object of the present invention to provide a novel winding arrangement of the concentric winding type.

It is a specific object of the present invention to provide a concentric winding arrangement that

permits connection of motor leads to windings at both ends of the stator core.

It is a specific object of the present invention to provide a novel winding arrangement that facilitates automated winding of stators intended for use in large electric motors.

Some of these objects are achieved by a stator assembly for an electromechanical machine comprising a magnetically permeable stator core. The core has a cylindrical inner surface defining a plurality of radial, axially-extending winding slots. At least six coil groups of electrical windings are also provided, each of the coil groups having a plurality of winding coils arranged concentrically. A predetermined number of winding coils within each group are singularly located in spaced apart pairs of winding slots. In addition, the remaining number of winding coils within each coil group is shared in spaced-apart pairs of winding slots along with coil sides of winding coils in other groups.

For example, each coil group may comprise a total of six winding coils. In such embodiments, two of the six winding coils may be singularly located in winding slots and the remaining four may share winding slots with other coil sides. Often, the magnetically permeable core may define a total of forty-eight winding slots.

Preferably, the stator core may comprise a number of power leads equal to the number of coil groups.

The power leads are preferably arranged such that an equal number will be connected to the electrical windings at each end of the stator core. For example, if the stator assembly has a total of six power leads, three of the power leads may be connected to electrical windings at each of the stator core's two ends.

Other objects of the present invention are achieved by a stator assembly for an electromechanical machine comprising a magnetically permeable stator core. The core has a cylindrical inner surface defining a plurality of radial, axially-extending winding slots. At least six coil groups of electrical windings are also provided, each of which has a plurality of winding coils arranged concentrically. The stator assembly includes a number of power leads equal to a number of coil groups. The power leads are connected to electrical windings at each end of the stator core.

The stator assembly may be configured having a total of six coil groups arranged to provide a three-phase, two-pole stator assembly. In such embodiments, three power leads are preferably connected to electrical windings at each end of the stator core.

It will often be advantageous to include a total of six winding coils within each of the coil groups. Two of the six winding coils are singularly located in winding slots and four of the six winding coils share winding slots with coils of other groups.

Still further objects of the present invention are achieved by a method of producing a stator assembly for use in an electromechanical machine. One step of the method involves providing a magnetically permeable stator core having a cylindrical inner surface defining a plurality of radial, axially-extending winding slots. At least six coil groups are also provided, each having a plurality of differently-sized winding coils. The coil groups are inserted into the stator core one at a time from alternating sides thereof.

According to exemplary methodology, each of the coil groups are inserted such that a predetermined number of winding coils are singularly located in spaced apart pairs of winding slots. A remaining number of winding coils may be placed in spaced apart pairs of winding slots along with coil sides of winding coils in other groups. Preferably, the coil groups may be inserted in the stator core such that winding coils that are singularly located in one coil group are positioned adjacent to winding coils that are singularly located in another coil group within a mutual phase.

Other objects, features and aspects of the present invention are provided by various combinations and subcombinations of the disclosed elements, as well as methods of practicing same, which are discussed in greater detail below.

### Brief Description of the Drawings

A full and enabling disclosure of the present invention, including the best mode thereof, to one skilled in the art, is set forth more particularly in the remainder of the specification, including  
5 reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a large motor frame having a stator assembly of the present invention installed therein;

10 Figure 2 is a perspective view of a stator assembly of the present invention;

Figure 3 is a perspective view, similar to Figure 2, of a prior art stator assembly having a concentric winding arrangement;

15 Figure 4 is a perspective view of a magnetically permeable stator core before electrical windings have been inserted into slots thereof;

20 Figure 5 is an enlarged fragmentary view of a portion of a stator assembly showing a concentric winding pattern according to the present invention;

Figure 6 is a chart illustrating a concentric winding pattern of the present invention;

25 Figure 7 is a diagrammatic representation of a stator core showing the manner in which the winding slots are filled according to the pattern of Figure 6;

Figure 8 is an end view of an automated winding machine that may be used in the production of a stator assembly according to the present invention;



Figure 9 is a side view of the automated winding machine, illustrating the manner in which the stator core is rotated for insertion of the next winding group;

5           Figure 10 is a perspective view of an insertion tool of the automated winding machine, the insertion tool having a coil group located thereon for insertion into the winding slots of a stator core;

10           Figure 11 is a perspective view of the insertion tool of Figure 10 showing the coil group being inserted into the winding slots of a stator core;

            Figure 12 is a perspective view showing use of the drift tool of the automated winding machine; and

15           Figures 13 and 14 illustrate the radially expanding members at the base of the drift tool.

            Repeat use of reference characters in the present specification and drawings is intended to represent same or analogous features or elements of the invention.

20           Detailed Description of Preferred Embodiments

            It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not intended as limiting the broader aspects of the present invention, which broader aspects are embodied in the exemplary constructions.

25           Referring now to Figure 1, a relatively large motor frame 10 is shown as it may appear at an intermediate stage in the manufacturing process. A

stator assembly has been installed in the frame at this stage, but other components have not. For example, frame 10 does not include a rotor, or the end bells that are later installed on the frame's open ends. Typically, frame 10 will conform to some applicable standard, such as NEMA 440.

Figure 2 illustrates a stator assembly 12 such as may be installed in frame 10. Stator assembly 12 includes a magnetically permeable stator core 14 having electrical windings located in a plurality of radial, axially-extending winding slots. The winding coils turn beyond the end faces of core 14, thus forming respective "coilheads" 16 and 18. In this example, the winding pattern achieves a three-phase, two-pole stator assembly. A trio of relatively small diameter power leads T1, T2 and T3 extends from both ends of the stator core.

A stator assembly 20 of the prior art is illustrated in Figure 3. Stator assembly 20 includes a stator core 22, which may be identical to stator core 14. Unlike stator assembly 12, however, the windings of stator assembly 20 are arranged in a known concentric winding pattern. This conventional winding arrangement includes six coil groups of eight coils each, connected to achieve a three-phase, two-pole stator assembly. Three large power leads T1, T2 and T3 extend from one end of core 22.

As noted above, the large power leads of the conventional arrangement have prevented the use of

concentric winding patterns in some large electric motors. Due to the current demands of these motors, the leads are simply too big to fit through the relatively small gap provided between the inner surface of the frame and the stator core's outer diameter.

The present invention overcomes this problem by allowing the connection of power leads at both ends of the stator core. This is illustrated in Figure 1, where one set of power leads T1, T2 and T3 are routed from a first end of stator assembly 12 to the conduit box opening of frame 10. Likewise, another set of power leads T1, T2 and T3 are routed from the opposite end of stator assembly 12 to the conduit box opening. Corresponding leads from each set are then connected together outside of the motor housing. Although the multiple leads are individually smaller, they have at least the same current carrying capacity when connected together as a larger single lead.

Referring now to Figure 4, stator core 14 is conventionally made of a plurality of core laminations arranged in a stack. Also in a conventional manner, winding slots 24 each contain an individual slot liner 26. The slot liners serve to insulate the metallic core from the electrical windings contained in that slot.

In the three-phase, two-pole stator assembly of the exemplary embodiment, six coil groups are provided, each of which has six concentric coils. One

coil group thus forms a single pole of a single phase, such that two coil groups are associated with each of the three electrical phases that will be used to drive the motor. Stator core 14 has a total of forty-eight winding slots in this case.

Figure 5 shows an enlarged portion of stator core 14 after one of the coil groups has been inserted therein. The four innermost coil sides 28, 30, 32 and 34 occupy the bottom portion of their respective winding slot. These winding slots will be shared with coils of another group, with the coils of different groups being insulated from each other by an insulative divider 36. The two outermost coil sides 38 and 40 are singularly located in their respective winding slot (i.e., these coils do not share the winding slot with others). The coils of these winding slots are preferably "capped" by an insulative top stick 42.

The winding pattern can be more fully understood with reference to the chart of Figure 6, which shows the contents of each winding slot. The number "5" indicates that the slot is filled by one side of a respective coil. On the other hand, the number "3" indicates that the slot is half full, and can be shared with a coil side of another coil. Thus, shared slots have a "slot fill" value of "6" while singular slots have a "slot fill" value of "5." This is also illustrated in Figure 7, where "full" slots are

indicated by "F," whereas shared slots are indicated by an "S."

For purposes of discussion, consider the coils of group A1. One side of the two outermost coils are located in winding slots 1 and 2, respectively. The other sides of these same coils are respectively located in slots 24 and 23. Similarly, one side of the four inner coils are located in slots 3, 4, 5 and 6. The other sides of these coils are respectively located in slots 22, 21, 20 and 19.

In a similar manner, the coils of group A2 are located in slots 25-30 and 43-48. Furthermore, corresponding groups of other phases are offset by  $60^\circ$  (eight slot positions). In other words, group B1 is separated by eight slot positions from group A1 and group C1.

According to this arrangement, full slots of one group within a phase will be adjacent to full slots in the other group within the same phase. For example, slots 23 and 24 will carry a full coil side from the outermost coils of group A1. Adjacent slots 25 and 26 will carry full coil sides from the outermost coils of group A2. This adjacent placement of full slots of different coil groups within a mutual phase is believed to eliminate some of the electrical imbalances present in concentric winding arrangements, thus yielding enhanced motor performance.

Like concentric winding arrangements of the prior art, the novel winding arrangement of the present

invention is amenable to insertion in the stator core using automated equipment designed for this purpose. In contrast to the prior art, however, the winding arrangement of the present invention can be employed in significantly larger motors. In these larger motors, manually-inserted lap winding arrangements have often been required in the past. Because automated equipment can now be used, the time required to wind one of these larger stator cores can be significantly reduced.

Figures 8 and 9 illustrate a machine 50 that can be utilized to produce the desired winding arrangement. Machine 50 includes a carriage 52 having thereon a stator core 54. As indicated by arrow 56, carriage 52 is movable to the left and right of the machine. Carriage 52 is also movable forward and back, as indicated by arrow 58.

Machine 50 includes two primary mechanisms that function to produce the wound core, insertion tool 60 (Figure 10) and an elongate drift tool 62. Typically, the coils of a coil group are first wound on a rotating coil form (not shown) located separate from machine 50. The coil group is then moved from the coil forms to insertion tool 60, such as by the use of a suitable transfer tool 64.

Referring now to Figures 10 and 11, stator core 54 is brought into position directly in front of insertion tool 60 when a coil group 66 has been placed thereon. Then, as shown in Figure 11, the coils are

drawn through the desired winding slots of stator core 54. Top sticks and insulative divider wedges are pushed into the winding slots at the same time. After the coils have been inserted into the slots in this manner, carriage 52 is moved into position in front of drift tool 62.

As shown in Figure 12, carriage 52 is next moved forward such that drift tool 62 will enter the opening of core 54. Because the core opening is slightly obstructed by the windings, drift tool 62 has a "bullet-shaped" end 64. End 64 is preferably made from a relatively smooth metal that tends to simply push the windings out of the way. A plurality of parallel bars 68, located on the side of drift tool 62, extend slightly into the winding slots, causing a respective coil side located therein to be compressed. This produces room for subsequent coil sides in winding slots that are to be shared.

As can be seen in Figures 13 and 14, the base of drift tool 62 comprises a plurality of expandable members 70. When core 54 has been moved to its fullest extent along drift tool 62, members 70 expand radially (as shown in Figure 14). Members 70 thus push the coilhead turns even farther out of the way, so that they will not interfere with the insertion of subsequent coil groups.

After one coil group has been inserted, core 54 is indexed so that the next set of winding slots will be in the proper angular position. According to the

prior art, subsequent coil groups were simply inserted in the same manner until all of the slots were filled. In other words, all winding groups were inserted from the same side of the stator core.

5 Referring again to Figure 9, the present invention utilizes a novel modification of the conventional procedure. Between each coil group, stator core 54 is rotated 180°, as shown by the arrow 72. As a result, successive coils are inserted from  
10 opposite sides of the stator core. This desirably produces coil ends on both sides of the stator core to which power leads can be connected.

In a winding arrangement having six coil groups, for example, three coil groups may be inserted from  
15 each end of the core. The first group, A1, is inserted in standard fashion, which may be referred to as a "forward" insertion in the context of the present invention. The stator core is then rotated, so that the group B1 can be inserted into the other end as a  
20 "reverse" insertion. Next, the stator core is rotated back to its original position, allowing insertion of group C1 as a forward insertion. Groups A2, B2 and C2 are then respectively inserted reverse, forward, reverse to complete the winding pattern. Because of  
25 this alternating coil group insertion, the process of the invention may be referred to as a "reverse wind" process.

Mechanically, the structure of machine 50 is similar to the prior art used to produce a standard



concentric winding arrangement. It is necessary, however, to modify such a machine from its prior art version in order to achieve the desired results. For example, carriage 52 should be modified so the centerline of the stator core will be at the same axial location in both "forward" and "reverse" positions. Various enhancements may also be made to the controlling software to produce the desired results.

It can be seen that the present invention provides a stator assembly for an electromechanical machine having a novel winding arrangement, as well as novel methodology for producing same. While preferred embodiments of the invention have been shown and described, modifications and variations may be made thereto by those of ordinary skill in the art without departing from the spirit and scope of the present invention, which is more particularly set forth in the appended claims. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to be limitative of the invention so further described in such appended claims.